

US EPA ARCHIVE DOCUMENT

# Source-Oriented Toxicology of Ambient Fine and Ultrafine PM

Anthony Wexler, Keith Bein, and Kent Pinkerton  
University of California, Davis

Work Sponsored by  
California Air Resources Board and  
Electric Power Research Institute

# Which Sources are more Toxic?

Is all PM created equal?

Is some PM more equal than others?

(apologies to George Orwell)

- Do sea spray and diesel exhaust have same toxicity?
- Current mass-based NAAQS treats them the same
- Can we differentiate sources by their toxicity?

# Which Sources are more Toxic?

How do we deduce health effects of different sources?

Epidemiologically

- High risk near freeways
- High risk downwind of coal fired power plants
- Many other studies
- But correlative, not causative

# Which Sources are more Toxic?

How do we deduce health effects of different sources?

Toxicologically directly from sources

- Well how about those nasty secondary compounds?
- And how about the atmosphere changing the toxicity?
- Can we collect source-oriented PM from the atmosphere?
- Isn't the atmosphere well mixed?

# Talk Outline

- Source-Oriented Sampling (Wexler)  
What did we do and how did we do it?
- Source Attribution (Bein)
- Source-Oriented Toxicity (Pinkerton)

# Source-Oriented Sampling

The atmosphere is not well mixed on short time scales

- Consider plumes hitting a sampling site
- Single particle mass spectrometer observations in Atlanta, Houston, Baltimore and Pittsburgh

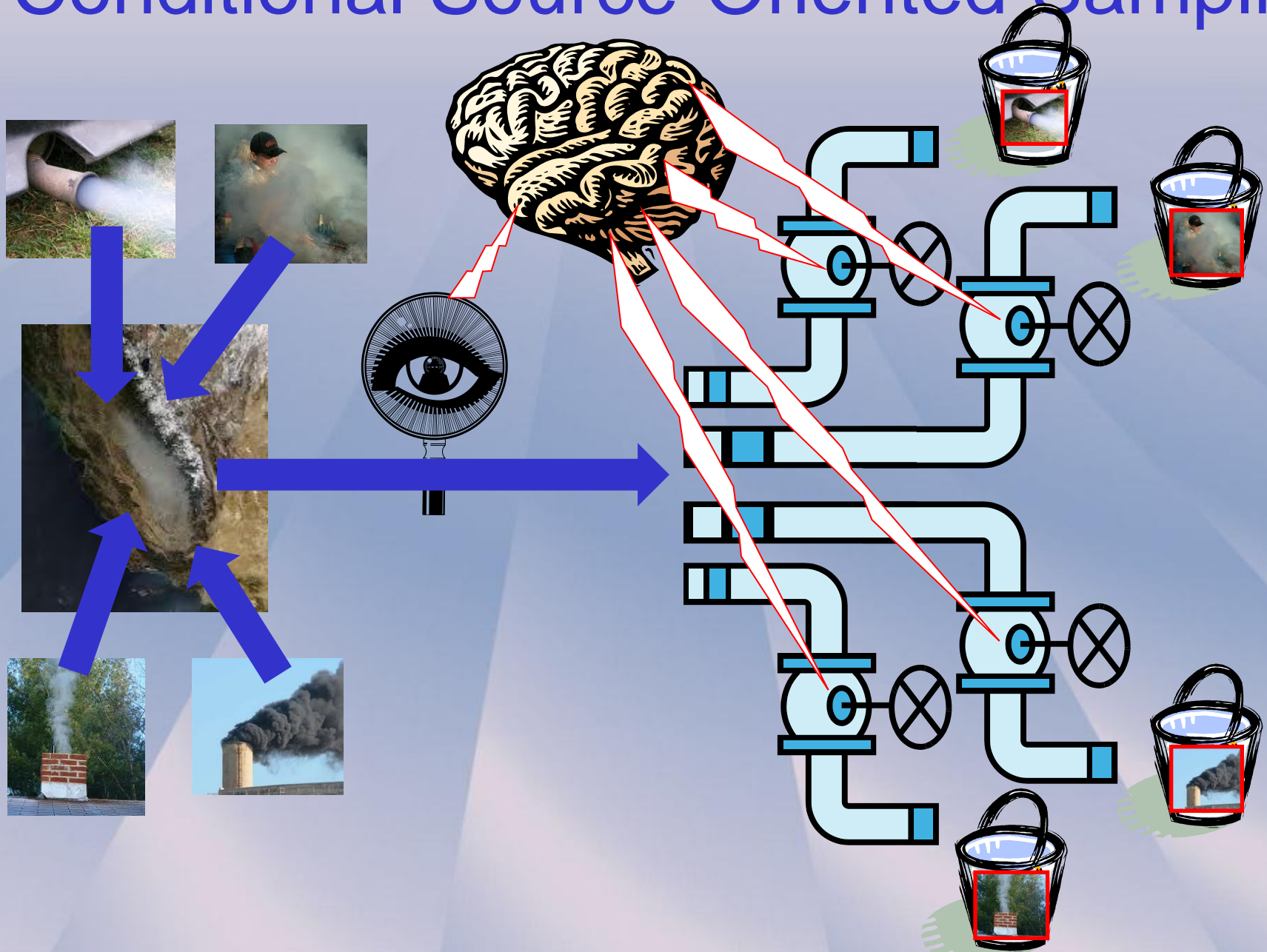
# Source-Oriented Sampling

So what's the big idea?

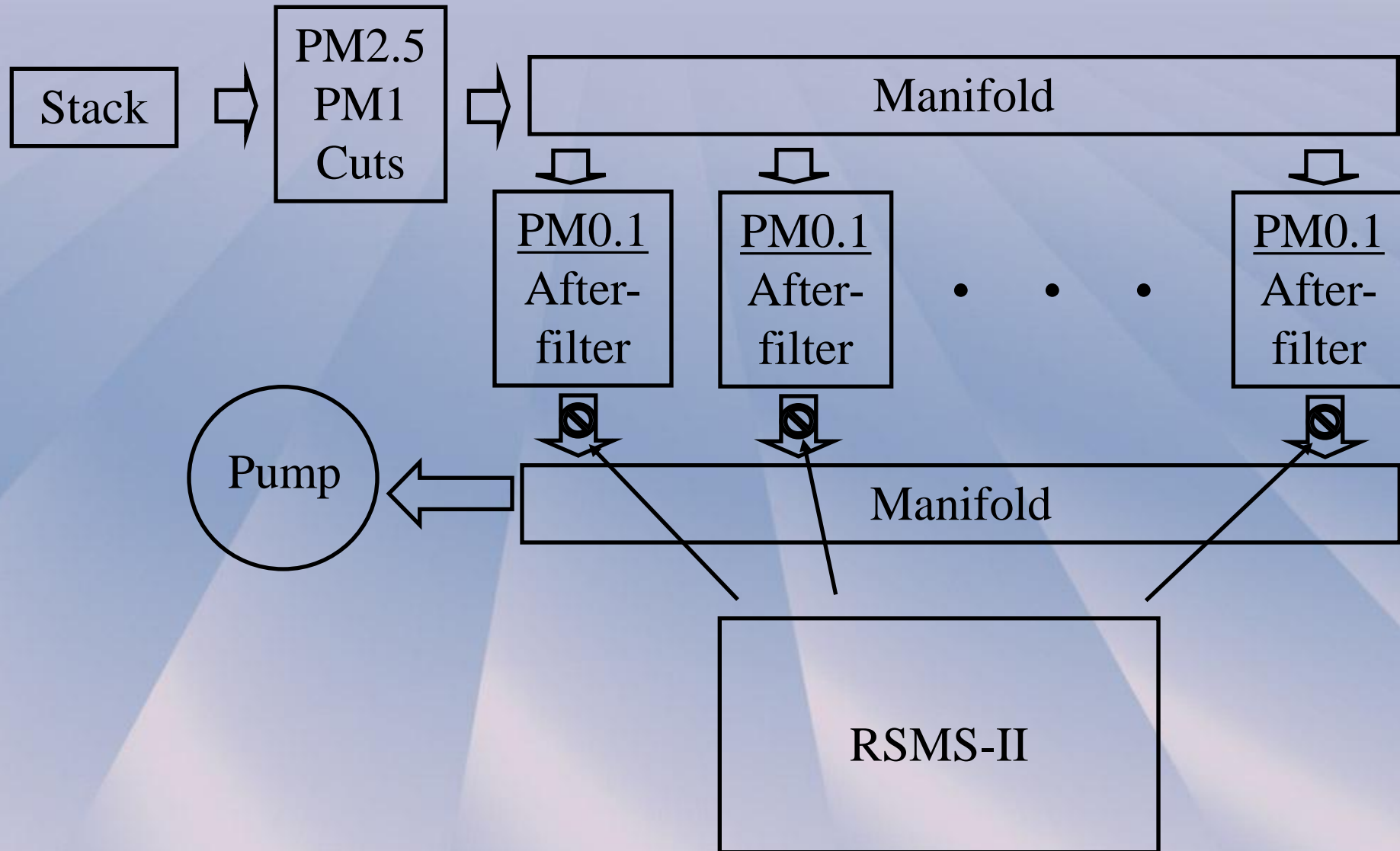
- Run a single particle mass spectrometer to characterize the mixing state of the atmosphere
- Assign prevailing sources or source combinations to each of 10 high-volume ChemVol samplers
- Use single particle mass spectrometer to select which ChemVol samples
- Collect enough PM for tox studies



# Conditional Source-Oriented Sampling



# Conditional Source-Oriented Sampling



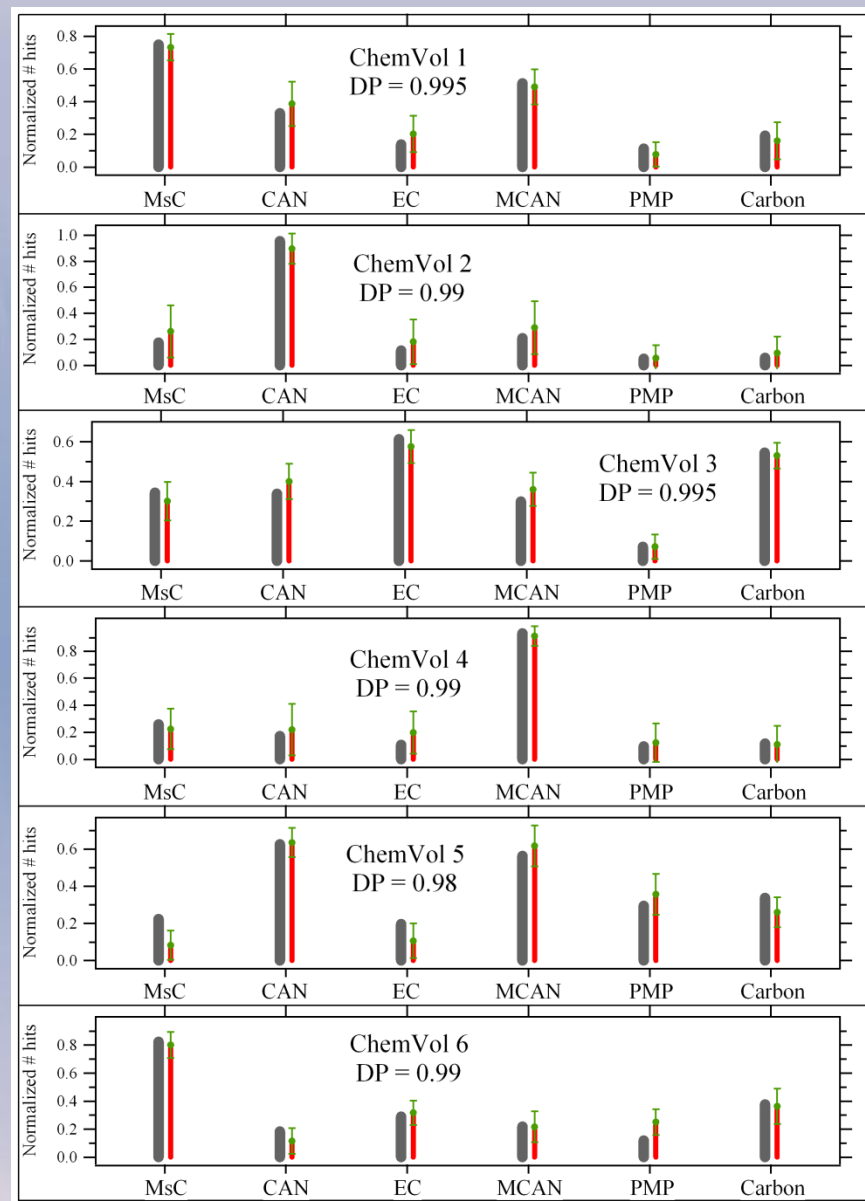
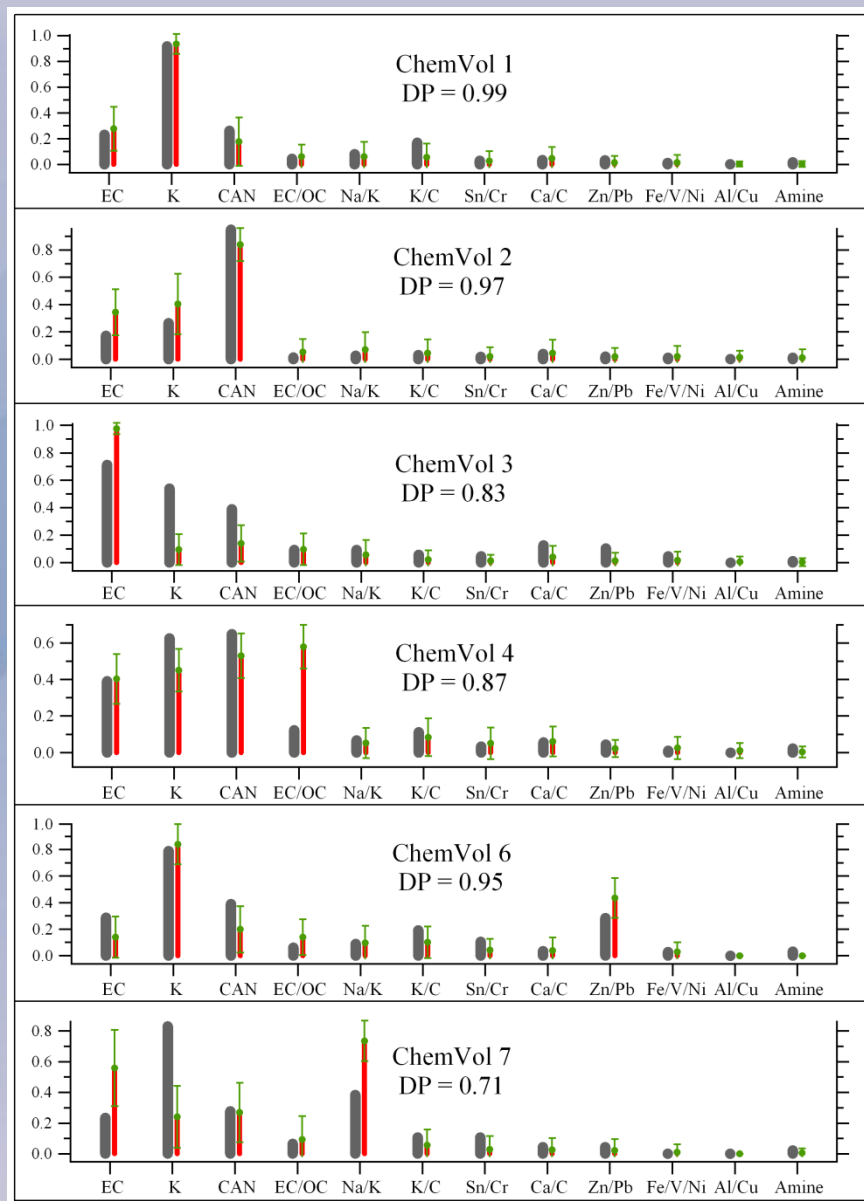
# Sampling Train



Summer 2008

# Fidelity

Winter 2009





# Source-Oriented Sampling

## Summary

- Collected source-oriented PM from Fresno
- Two seasons: Summer '08 and Winter '09
- Two size ranges
  - Ultrafine (UF): smaller than 170 nm
  - Submicron Fine (SMF): 170 nm to 1  $\mu$ m
- Sufficient sample in most sources/sizes for tox studies
- Samples represent major sources in Fresno
- Good separation of sources in the samples

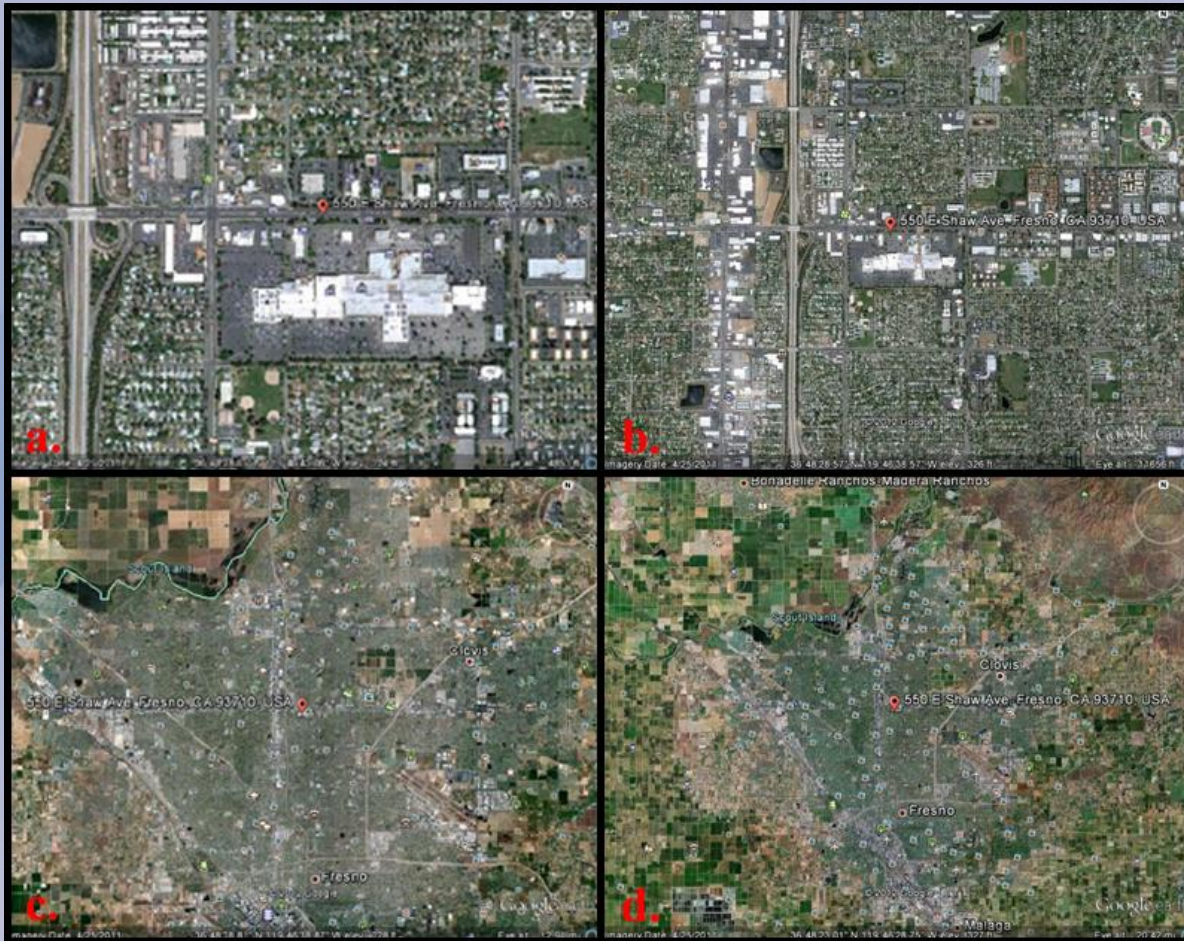
# Talk Outline

- Source-Oriented Sampling (Wexler)
- Source Attribution (Bein)
  - Where did the PM come from?
- Source-Oriented Toxicity (Pinkerton)

# Source Attribution – Site-Source Relation

## Emissions Sources

- Vehicular
  - Gasoline and diesel
  - Highways and residential
- Residential and Commercial
  - Cooking
  - Space heating
  - Construction/landscaping
- Agricultural
  - Ranching
  - Agricultural machinery
  - Waste/debris burning
  - Product transportation
- Regional Processing
  - Ammonium nitrate
  - Secondary Organic Aerosol
- Long-range Transport
  - Wildfires
  - Trans-Pacific transport

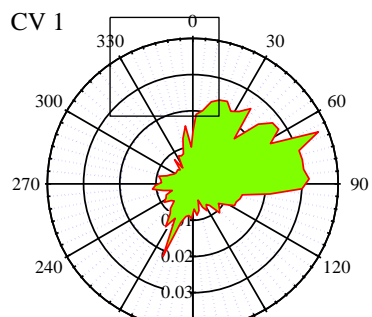




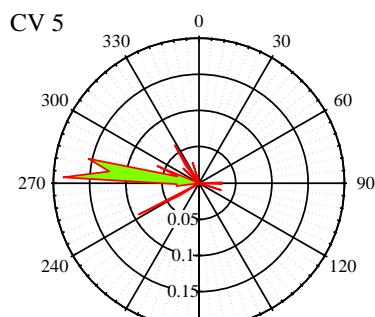
# Source Attribution – Directional Relation

Summer 2008

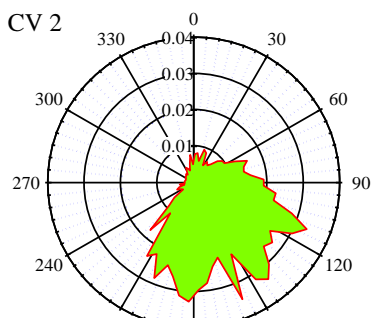
Winter 2009



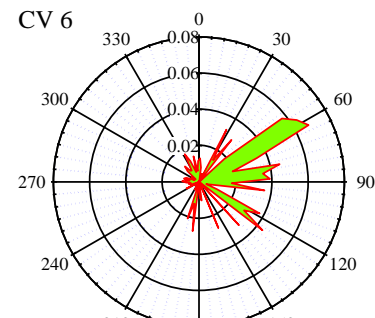
a. Residential Cooking



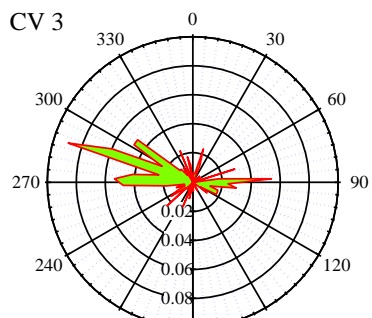
Vehicular – Gas + Diesel



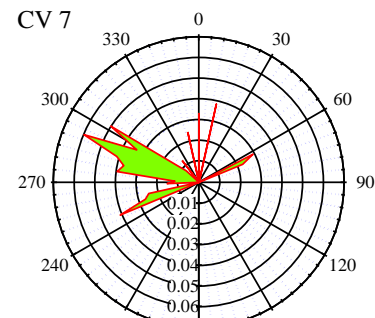
b Regional Background



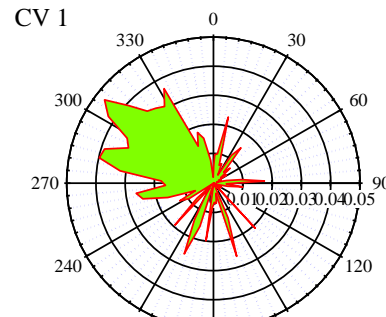
e Metals – Unknown



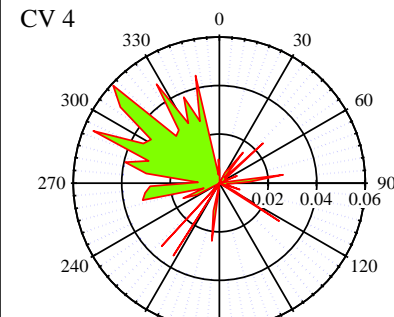
c. Vehicular – Diesel



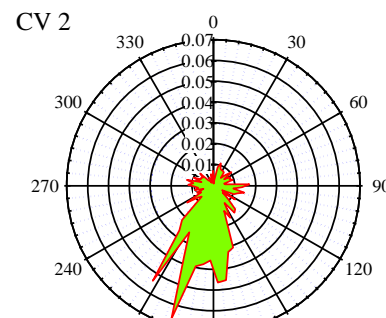
f. Commercial Cooking



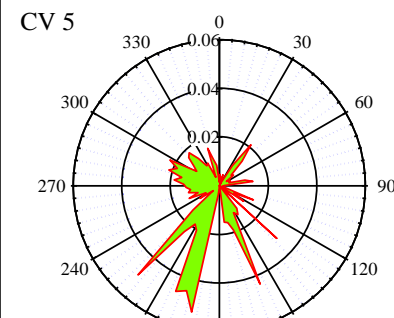
a. Residential Heating



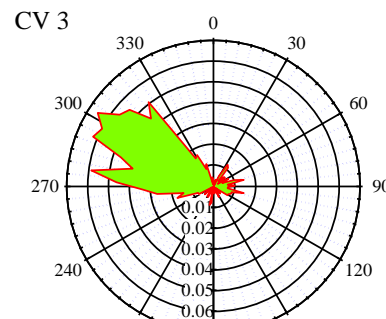
d. Processed Biomass



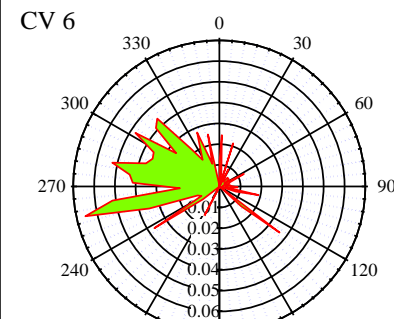
b. Regional Background



e. Regional Mixture



c Vehicular – Gas + Diesel



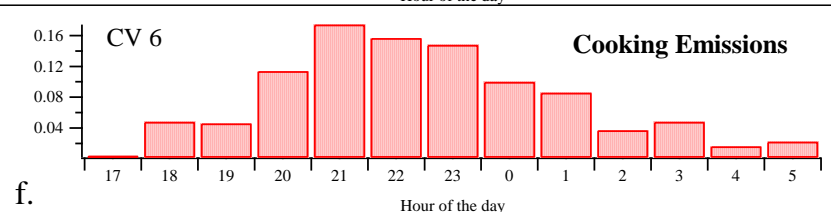
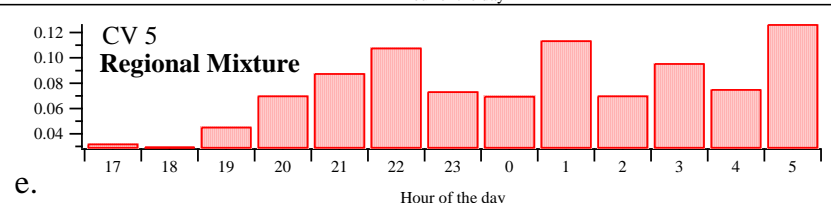
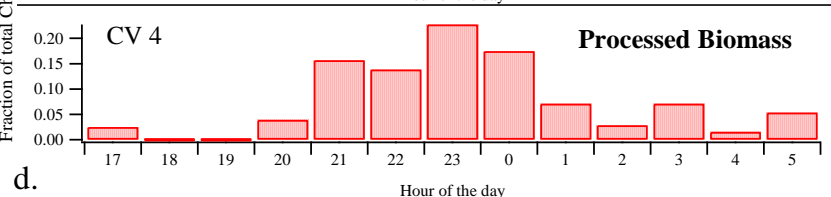
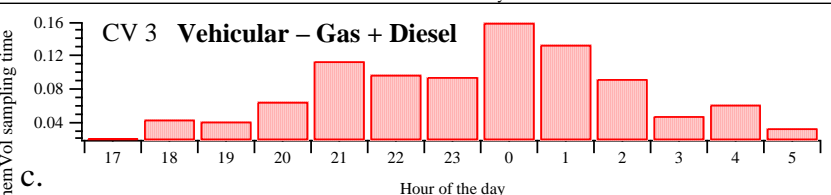
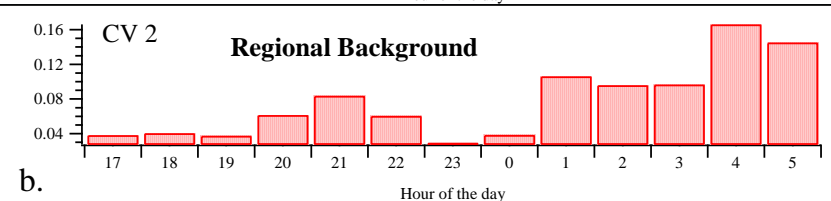
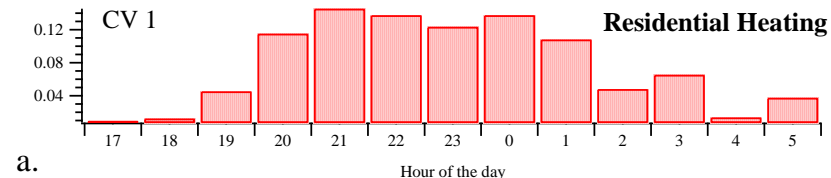
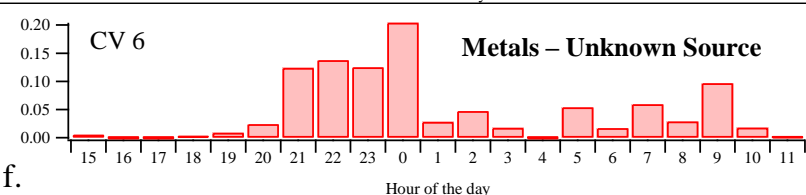
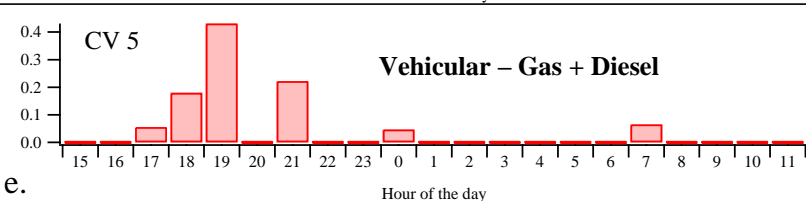
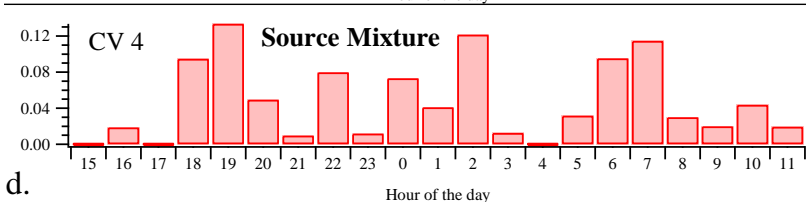
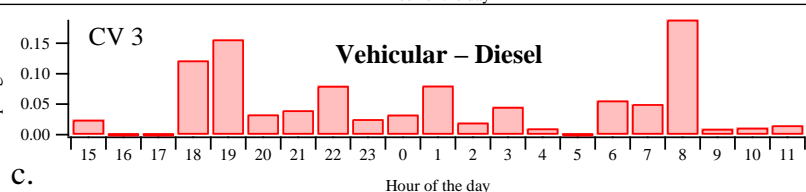
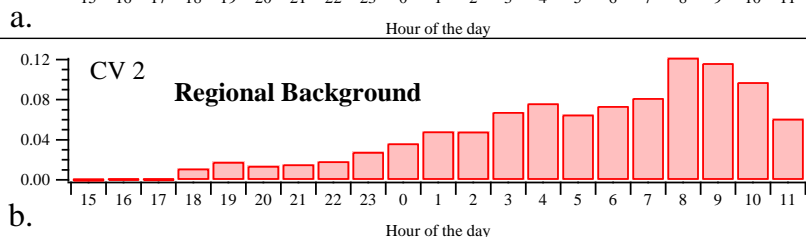
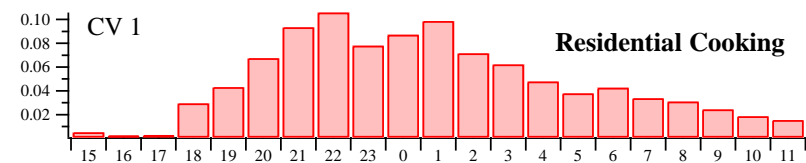
f. Cooking Emissions



# Source Attribution – Temporal Relation

## Summer 2008

## Winter 2009



# ChemVol Source Combination Reconciliation

Experiment:	Summer 2008		Winter 2009	
ChemVol	Dominant Particle Type(s)	Dominant Source(s)	Dominant Particle Type(s)	Dominant Source(s)
1	K	Local cooking emissions	K/EC/OC	Local residential heating
2	CAN	Highly processed regional background PM	CAN	Highly processed regional background PM
3	EC	Local vehicular emissions; diesel	EC; EC/OC	Local vehicular emissions; gas + diesel
4	CAN; K; EC/OC	Source Mixture	K/CAN	Highly processed biomass combustion PM
5	EC; EC/OC	Local vehicular emissions; gas + diesel	CAN; K/CAN	Regional source mix; vehicular, biomass + ag
6	Metals	Unknown	K/EC/OC	Local cooking emissions
7	K; Na/K	Local cooking emissions	Timed ChemVol ~ 17:00-20:00	Evening commute and dinnertime cooking
8	N/A	ChemVol not used	Timed ChemVol ~ 09:00-17:00	Morning commute
9	Timed ChemVol ~ 11:00-15:00	Daytime mixed layer	Timed ChemVol ~ 09:00-17:00	Daytime mixed layer
10	Undifferentiated	Nocturnal inversion	Undifferentiated	Nocturnal inversion

# Talk Outline

- Source-Oriented Sampling (Wexler)
- Source Attribution (Bein)
- Source-Oriented Toxicity (Pinkerton)

Which sources are toxic and how are they toxic?

# Source-Oriented Toxicity

## Study Design



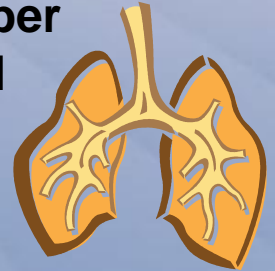
50  $\mu$ g  
Source-  
Oriented  
PM



24 hours  
post-  
exposure

### Bronchoalveolar Lavage (BAL)

- Total Cell Number
- Cell Differential
- Cell Viability
- Cytotoxicity
- Cell Damage



### Blood (CBC)

- Total Cell Number
- Cell Differential
- Hematology



### Reactive Oxygen Species

- Hydrogen peroxide
- Hydroxyl radical

# Source-Oriented Toxicity

## Definition of End Points

### **Bronchoalveolar Lavage (BAL)**

- **Total Cell Number** – elevation is indicator of injury
- **Neutrophils** – elevation indicates acute inflammation
- **Eosinophils** – elevation indicates allergic response
- **Protein** – elevation indicates cell injury
- **LDH** – elevation indicates cell death

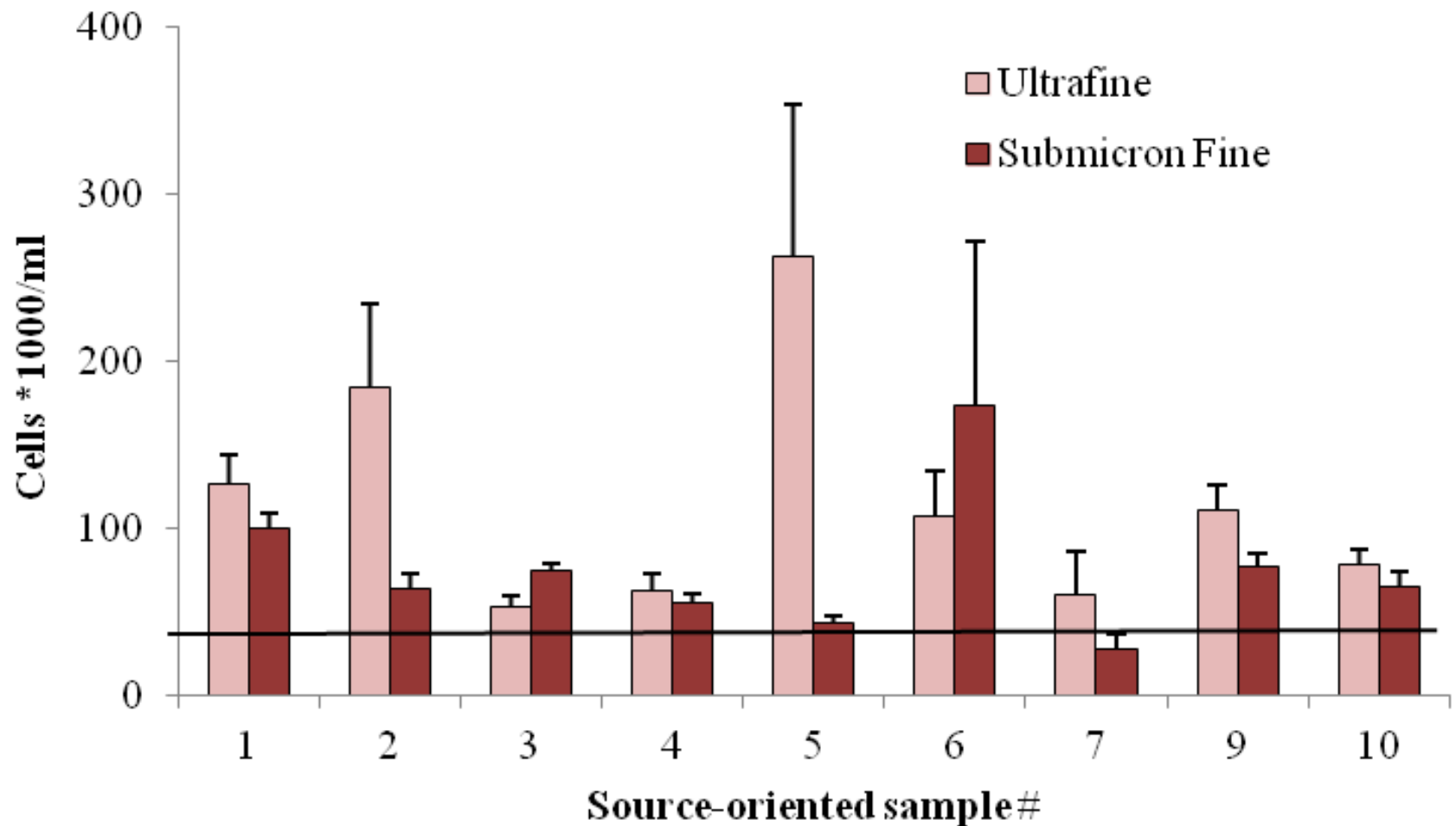
### **Blood (CBC)**

- **Neutrophils** – depletion suggests recruitment to lung

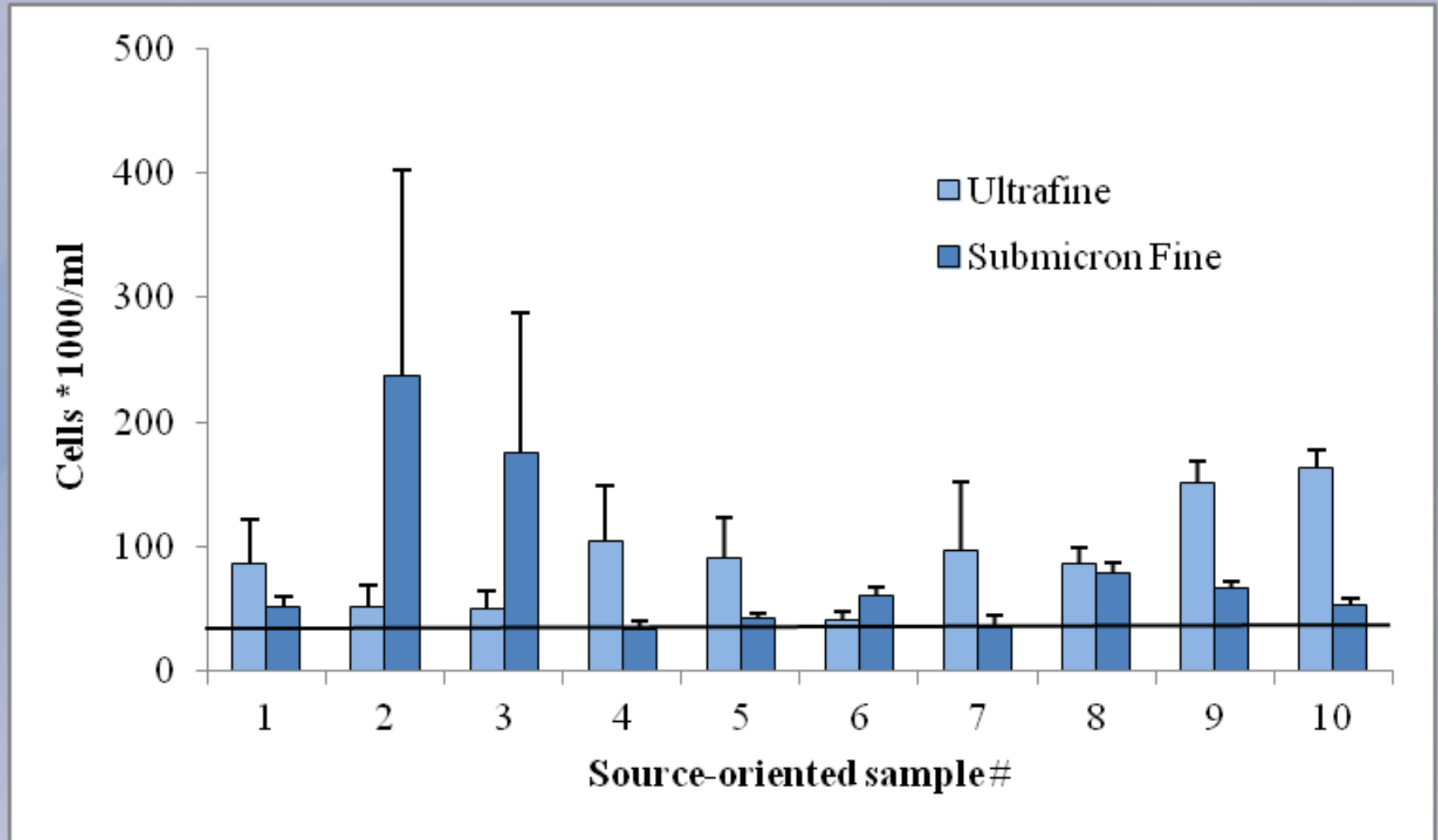
### **Reactive oxygen species – can induce DNA and cell membrane damage**

- **Hydrogen peroxide**
- **Hydroxyl radical**

# Summer Bronchoalveolar Lavage (BAL)

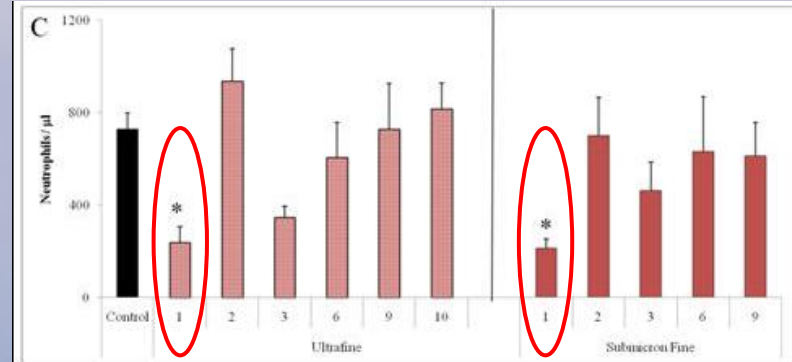


# Winter Bronchoalveolar Lavage (BAL)

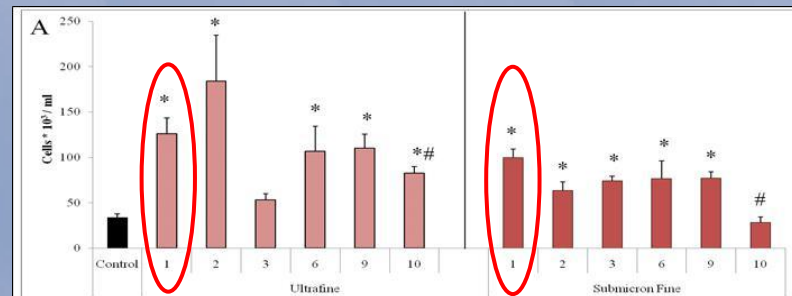


# Summer Residential Cooking

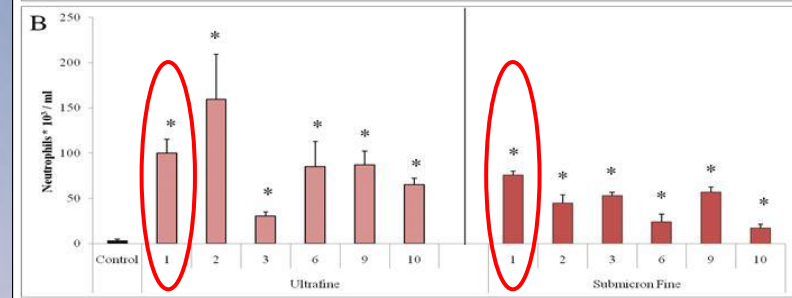
Circulating Neutrophils



Lung BAL:  
Total Cells



Neutrophils



Lung BAL protein:

Significant elevation in Summer Commercial Cooking

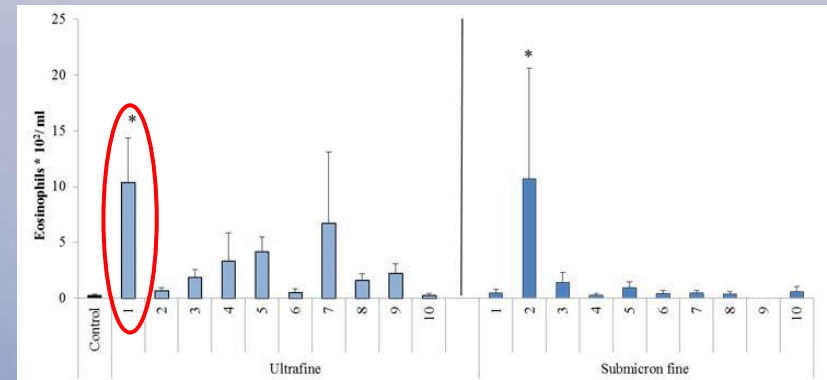


# Winter Cooking

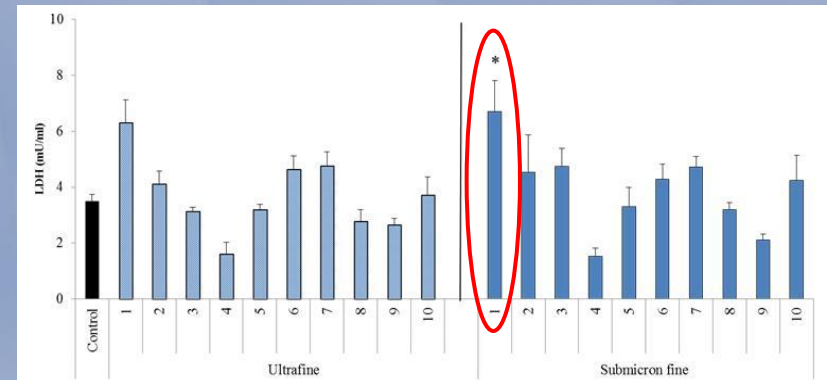
Relatively Little Pulmonary or Systemic Effects Found

# Winter Biomass Combustion

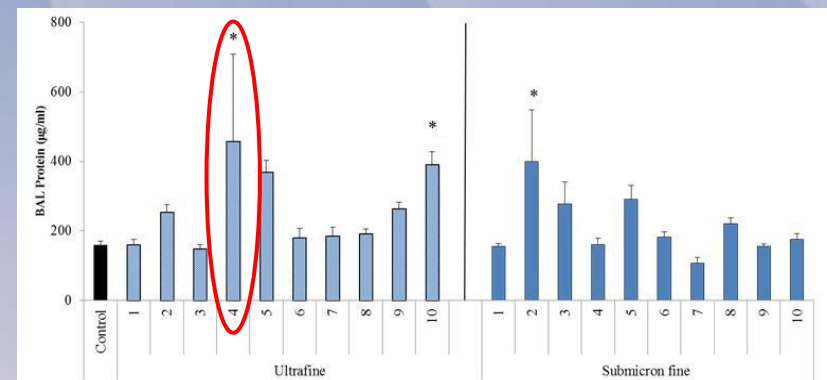
Lung BAL:  
Eosinophils



LDH

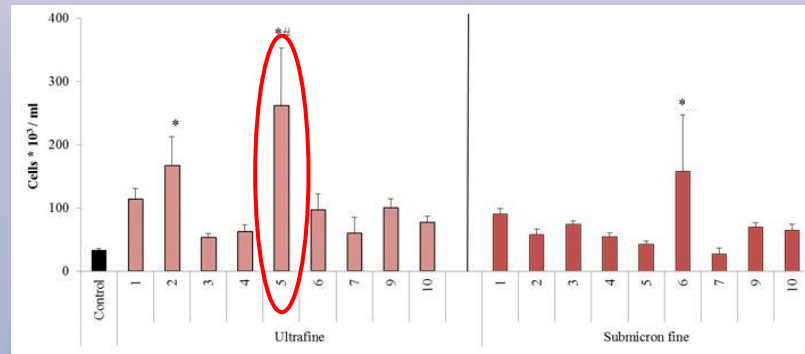


Protein

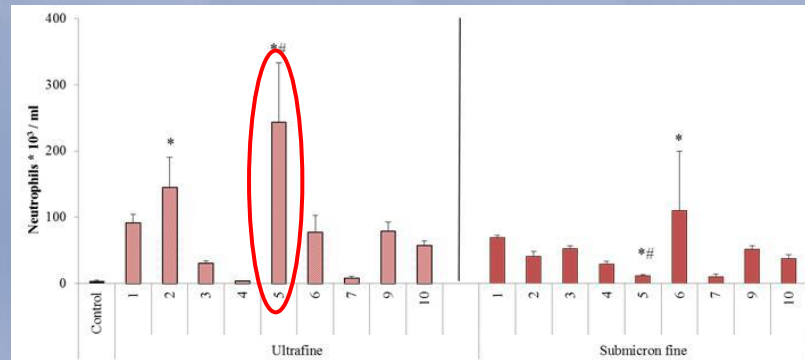


# Vehicles in Summer

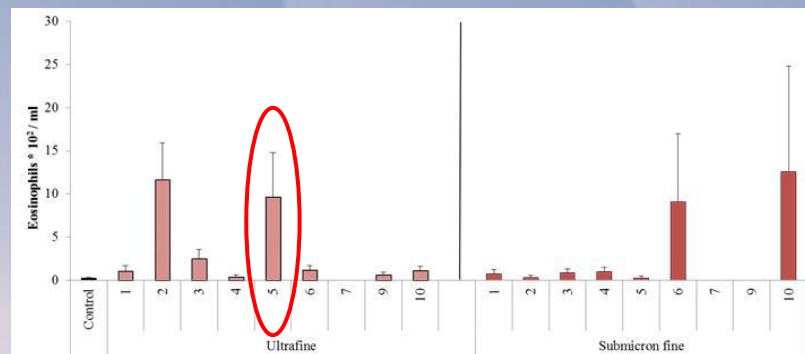
Lung BAL:  
Total Cells



Neutrophils



Eosinophils

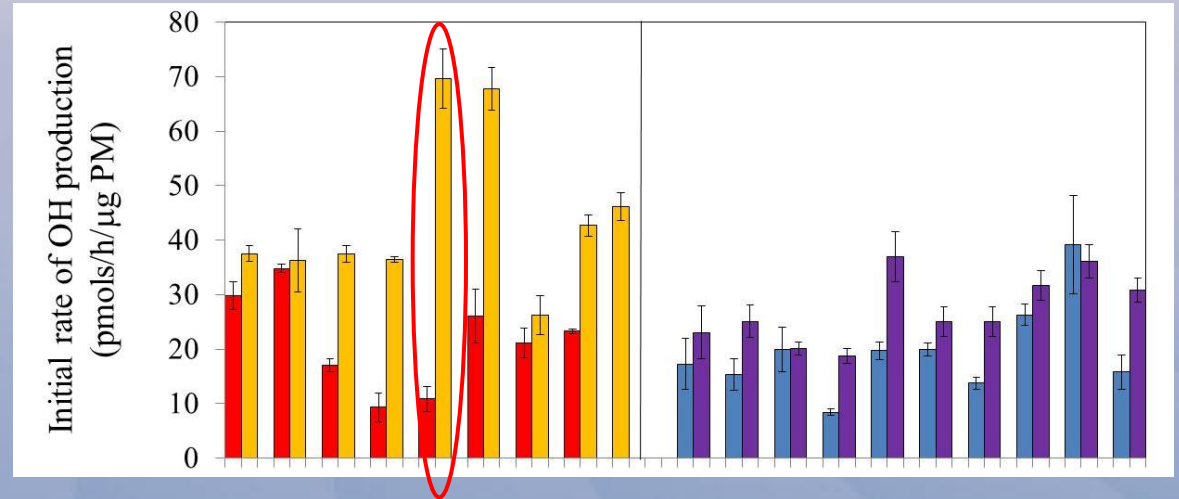


No Effects from the Vehicle mix with more Diesel

# Vehicles in Summer

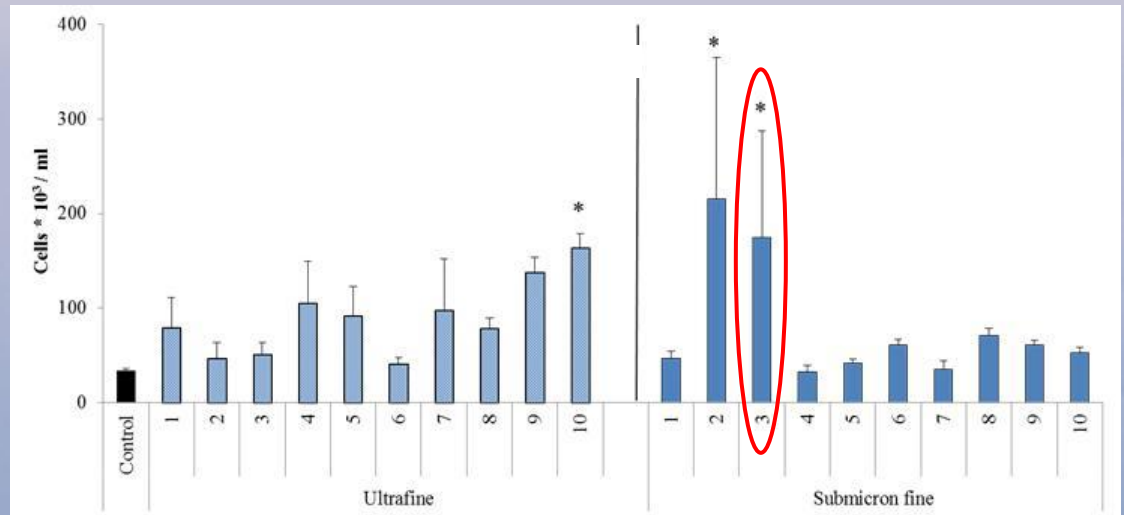
Reactive Oxygen  
Species: OH

Submicron Fine

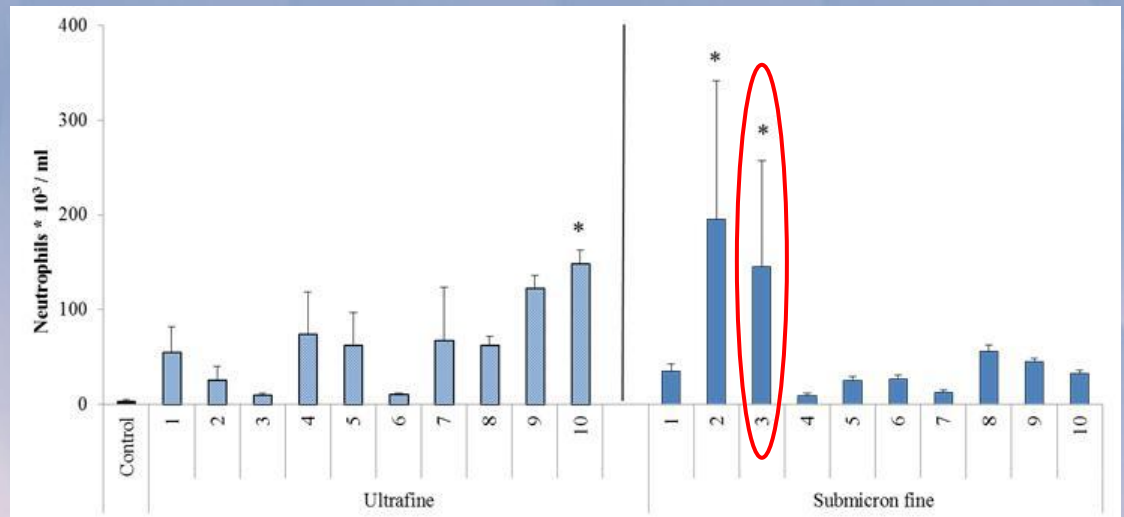


# Vehicles in Winter

Lung BAL:  
Total Cells



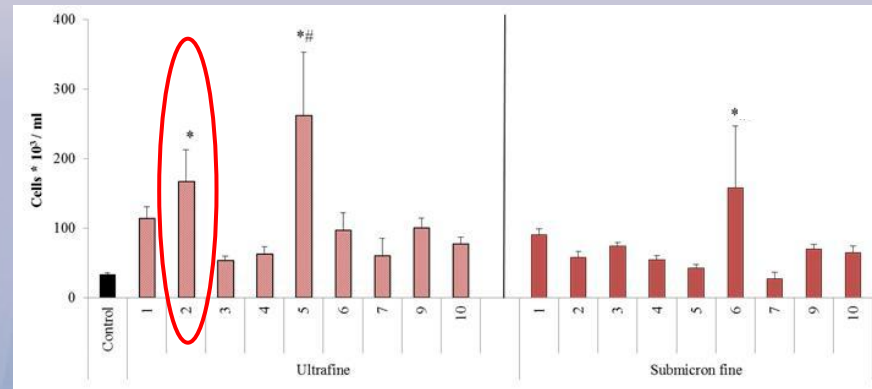
Neutrophils



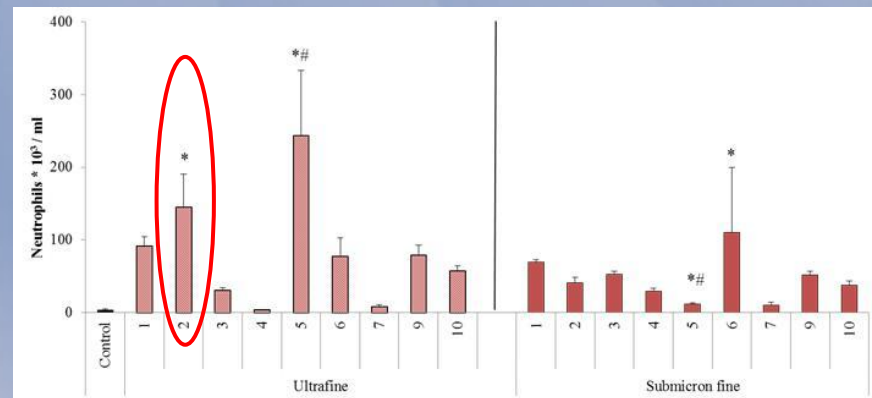
Systemic Effects in Morning Commute Hours

# Summer Processed Regional Background

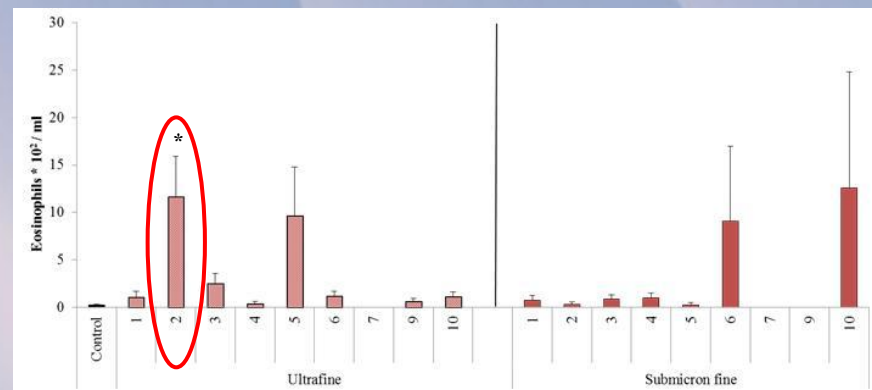
Lung BAL:  
Total Cells



Neutrophils

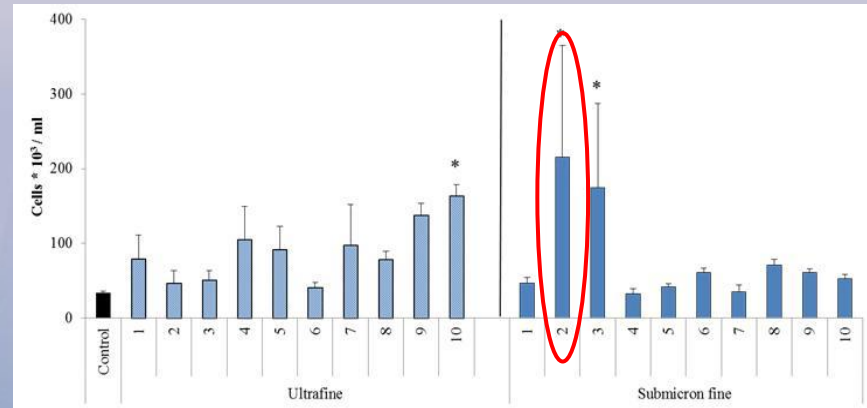


Eosinophils

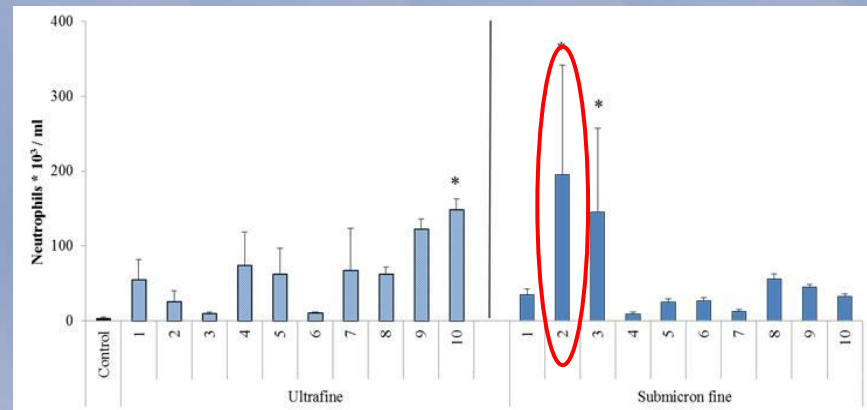


# Winter Processed Regional Background

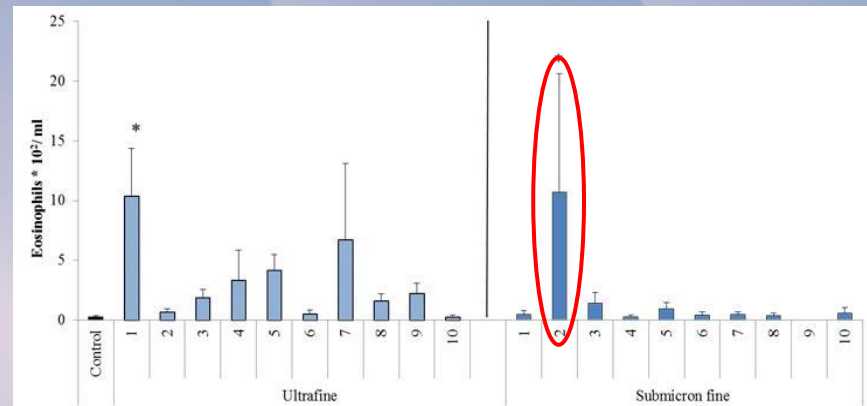
Lung BAL:  
Total Cells



Neutrophils

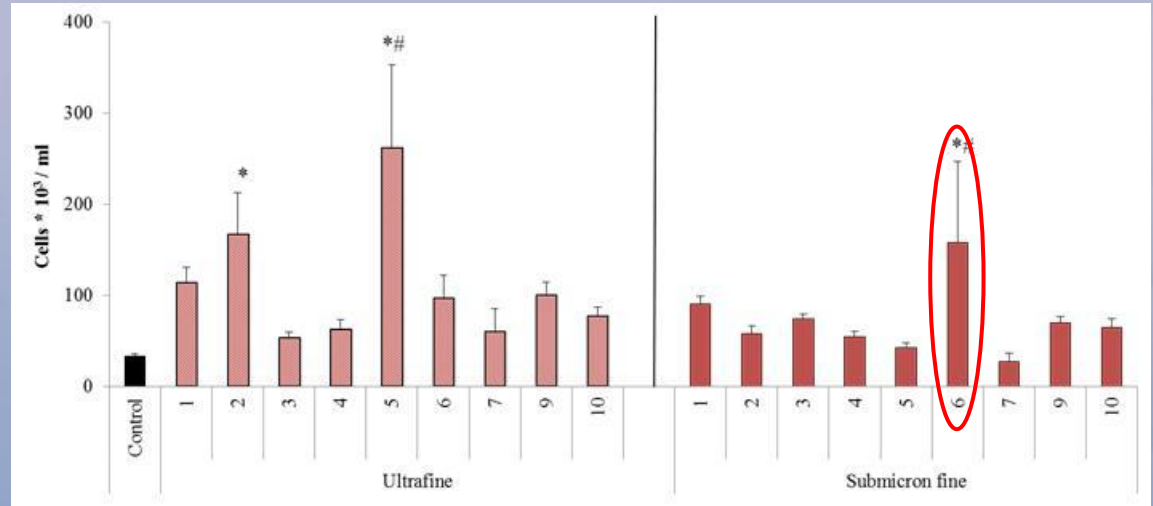


Eosinophils

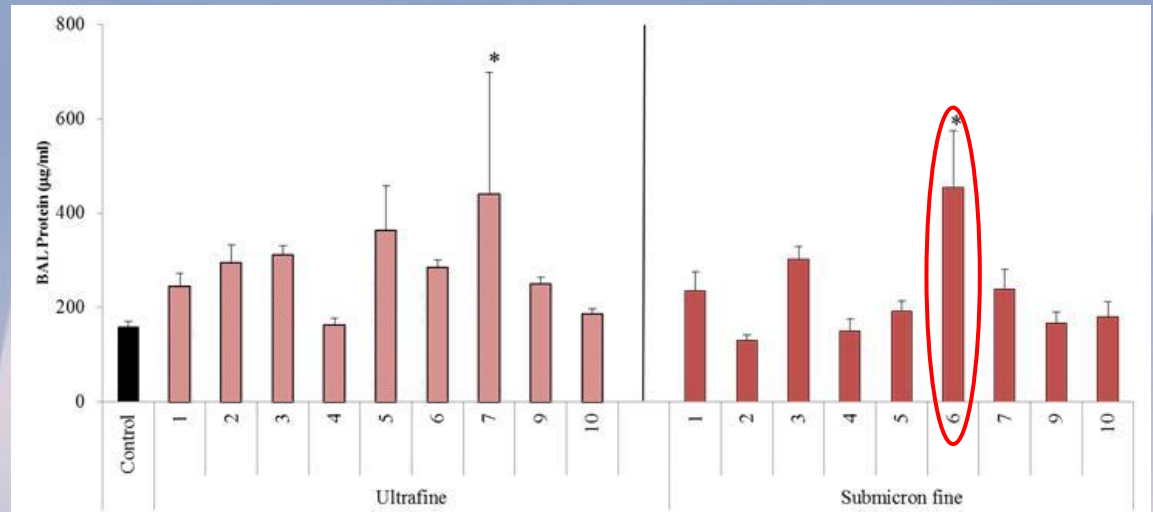


# Summer Metals

Lung BAL:  
Total Cells



Protein

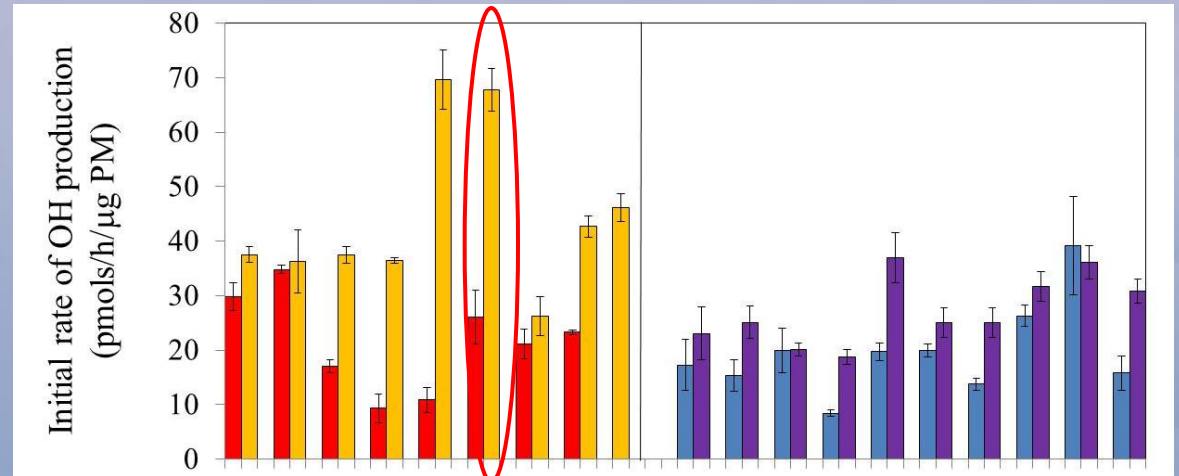




# Summer Metals

# Reactive Oxygen Species: OH

## Submicron Fine



# Conclusions

## Source-Oriented Sampling

- Source-oriented sampling is FEASIBLE
  - Novel sampling method implemented successfully
  - Different PM samples attributable to different sources
  - Sufficient PM collected for toxicity studies

# Conclusions

## Source-Oriented Toxicity

- Some particles MORE TOXIC than others
  - Summer PM: metal-containing and vehicular emissions have largest biological response
  - Winter PM: highly processed, vehicular emissions and nighttime mix have largest biological response
  - Ultrafine PM generally elicits greater biological response than submicron fine PM
- Different particles TOXIC in DIFFERENT ways
- Source-oriented regulations are FEASIBLE but further research is necessary
- More Complete CARB presentation:  
<http://www.arb.ca.gov/research/seminars/seminars.htm>